PY410 / 505
Computational Physics 1

Salvatore Rappoccio

Code

- Code is in CompPhys/ReviewCpp/BasicExamples

Expressions and Arithmetic

C++: Expressions and Arithmetic

- An expression is a sequence of operators and operands that specifies a computation
- Arithmetic is just like in regular math, but can happen on other types besides numbers!

C++: Expressions and Arithmetic

- We've already seen the standard OUTPUT in C++ (cout)
- Now to take a look at standard INPUT in C++ (cin)
- We will use cin to get two values and compute their sum
  - Enter them in order with a space between

- Go to CompPhys/ReviewCpp/BasicExamples/addition.cc

```
#include <iostream>
int main() {
  int value1, value2, sum;
  std::cout << "Please enter two integer values: ";
  std::cin >> value1 >> value2;
  sum = value1 + value2;
  std::cout << value1 << " + " << value2 << " = " << sum
<< '\n';
}
```

- Then compile and execute

C++: Expressions and Arithmetic

- What are we looking at? Individual expressions ALWAYS evaluate to a value
- Examples:

```
42;                             // value: 42
sum = value1 + value2;          // value: “sum”
12 > 13;                        // value: false
```

C++: Expressions and Arithmetic

- Arithmetic operators behave basically how you expect

Operator	Meaning
+	addition
–	subtraction
*	multiplication
/	division
%	modulus

- Can have BINARY operators (two operands) or UNARY operators (one operand)
  - For arithmetic operators, only “+” and “-“ can be unary

C++: Expressions and Arithmetic

- Logical operators work on individual boolean variables:

e_1	e_2	e_1 && e_2	e_1 || e_2	!e_1
false	false	false	false	true
false	true	false	true	true
true	false	false	true	false
true	true	true	true	false

C++: Expressions and Arithmetic

- Bitwise operators do the same thing, bit by bit:
  - and (&)
  - or (|)
  - exclusive or (^)
  - bit shift left (<<)
  - bit shift right (>>)

C++: Conditional Execution

- All CONDITIONS in C++ evaluate to bools

- Possible conditions:

Operator	Meaning
==	Equal to
<	Less than
>	Greater than
<=	Less than or equal to
>=	Greater than or equal to
!=	Not equal to

Table 5.1: C++ Relational operators

- Now you can see the boolean VARIABLES assigned to the output of EXPRESSIONS:

```
bool expression = 14 < 16;
std::cout << expression << std::endl;
```

Logical versus Bitwise Operators

- bitwise comparison of “5” and “4:

```cpp
#include <iostream>


int main(void) {
  unsigned int i = 0x5;
  unsigned int j = 0x4;
  unsigned int k = i | j;
  unsigned int l = i & j;
  unsigned int m = i ^ j;
  std::cout << "i   = " << std::hex << i << std::endl;
  std::cout << "j   = " << std::hex << j << std::endl;
  std::cout << "i|j = " << std::hex << k << std::endl;
  std::cout << "i&j = " << std::hex << l << std::endl;
  std::cout << "i^j = " << std::hex << m << std::endl;
  return 0;
}
```

- Output:

```
i   = 5
j   = 4
i|j = 5
i&j = 4
i^j = 1
```

C++: Expressions and Arithmetic

- Example: operators.cc

```
#include <iostream>
int main(void) {

  std::cout << -5 << std::endl;
  std::cout << 5 + 3 << std::endl;
  std::cout << 5 * 3 << std::endl;
  std::cout << 21.32 / 38.0 << std::endl;
  std::cout << 12 / 4 << std::endl;
  std::cout << 13 / 4 << std::endl;
  std::cout << 13. / 4. << std::endl;
  return 0;
}
```

- Compile and execute, and answer:
  - Which of these does not behave the same as you would expect?
  - What is the difference between the last two expressions?

C++: Expressions and Arithmetic

- Arithmetic has to be done on TYPES
  - Types remain constant throughout the operation!
- Examples:
  - “int + int = int”
  - “int - int = int”
  - “int * int = int”
  - “int / int = int”

- But wait! The last one is dodgy… fractions are NOT integers!
  - Integers are NOT CLOSED under division!

C++: Expressions and Arithmetic

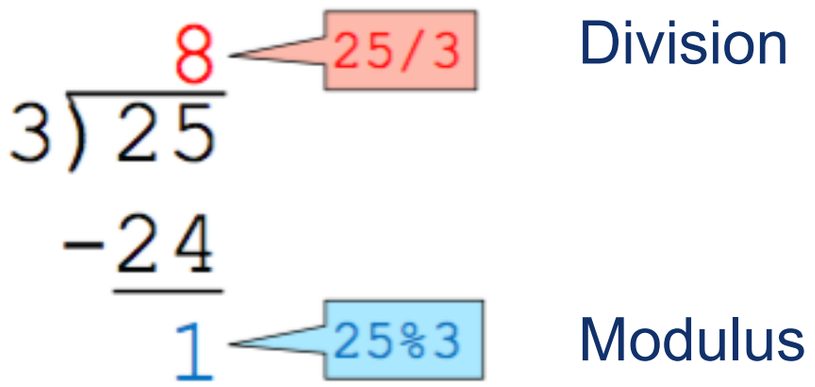
- So how do we handle integer division?
  - The the same way ALL division is handled in C++

Truncation, truncation, truncation

- As integers:
  9 / 3 = 3
  10 / 3 = 3
  11 / 3 = 3
  12 / 3 = 4

C++: Expressions and Arithmetic

- Integer division and modulus:



Division

Modulus

- Division gives you the number of times the divisor (3) evenly goes into the dividend (25), i.e. 8

- Modulus gives you the remainder, i.e. 1

- Can be used in lots of applications (like, arrays! more later on that)

C++: Expressions and Arithmetic

- If you want ratios and fractions, you need floats or doubles!
- This is why “13 / 4” is different from “13. / 4.”

- 13/4 gives you 3 (int)
- 13./4. gives you 3.25 (float or double)

- What about MIXED TYPE? 13. / 4 = ?

- Go to mixed.cc

C++: Expressions and Arithmetic

- Integers are a subset of reals
  - Therefore “int” can always be converted to “float” or “double”
  - The way we say this is int is “narrower” than float, and float is “wider” than int

- However, the converse is NOT true: this is called “narrowing”
  - Cannot represent 1.9 as an int

- The C++ standard says : TRUNCATION, TRUNCATION, TRUNCATION
  - It does NOT round!!!
    “int i = 1.999999” gives you “1”, not “2”

  - Some compilers will warn you (“potential loss of data”)
  - Other compilers will happily give you the garbage you asked for.

C++: Expressions and Arithmetic

- If you have an expression with MIXED TYPES, the standard will “widen” the narrower one
  - so “float / int” will give you a “float”
  - Also “int / float” will give you a “float”
  - But remember “int / int” will give you an “int”

C++: Expressions and Arithmetic

- This is a whole lot of guessing, though
- Better way is called “casting”
  - What we did before was IMPLICIT casting
  - We now EXPLICITLY cast

- Several casting cases are possible, but we will focus on the first one now: “**static_cast**”.

```
int j = static_cast<int>( g );
std::cout << j << std::endl;
```

- This says “interpret g as an integer, assign it to j”.
- We will go through other casts later

- static_cast is better because it can be checked at COMPILE TIME (very beneficial later on)

C++: Expressions and Arithmetic

- Operator precedence and associativity:

  – Follows same rules you've always learned:

  "Please Excuse My Dear Aunt Sally"
  =
  Parentheses, Exponentiation, Multiplication, Division, Addition, Subtraction

- Associativity also follows this

- But! Use parentheses to be clear when necessary!
  f = 2 + 3*4;
  and
  f = 2 + (3*4);
- Both correct, but second is clearer

C++: Expressions and Arithmetic

- Formatting and whitespace : C++ does not care about either. All of these are okay:

```
#include <iostream>

int f1(void){ return 1;}
int f2(void){
  return 2;
}

int
f3
(void)
{
return
  3;
}

int main(void){


  std::cout << f1() << std::endl;
  std::cout << f2() << std::endl;
  std::cout << f3() << std::endl;

  return 0;
}
```

C++: Expressions and Arithmetic

- CANNOT put whitespace in between variable names or within an operator
- MUST have whitespace between type and variable name.

- These are OK:

```
int my_int = 0;
float MyFloat = 0.0;
```

- These are not:

```
double My Double = 0.0;
charMyChar('a');
```

C++: Expressions and Arithmetic

- "Shortcut" operators and "optimization" operators
- There are other operators that are shorthand for a combination
- Example: Incrementing a value:

```
x = x + 1;
```

- Can also be written as

```
x++;
```

- OR!

```
++x;
```

- "Post-increment" and "pre-increment" operators
- Also have "minus minus"

C++: Expressions and Arithmetic

- Post-increment versus pre-increment:
  - Post: increment AFTER statement is executed
  - Pre: increment BEFORE statement is executed

- If just alone, no difference. These are equivalent:

```
int x  = 0;
x = x  + 1;
x++;
++x;
```

- If inside more complicated statement, there is a difference:

```
int x1 = 1;
int x2 = 1;
int y1 = ++x1;
int y2 = x2++;

std::cout << "x1 = " << x1 << ", y1 = " << ++x1 << std::endl;
std::cout << "x2 = " << x2 << ", y2 = " << x2++ << std::endl;
```

- gives:

```
x1 = 2, y1 = 2
x2 = 2, y2 = 1
```

Conditional Execution

C++: Conditional Execution

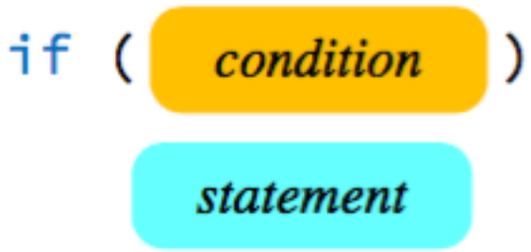
- The execution can then be CONDITIONAL upon the outcome of a boolean variable

- Simplest format is the “if/else” formalism

e_1	e_2	e_1 && e_2	e_1 || e_2	!e_1
false	false	false	false	true
false	true	false	true	true
true	false	false	true	false
true	true	true	true	false

C++: Conditional Execution

- This works exactly as you expect, but pedantically:



- Example:

```
int i1 = 0;
if (i1 < 2) {
  std::cout << "i1 is too small. Eat more." << std::endl;
}
```

- Note:
  - The statement is ONLY ONE STATEMENT
    - If you want multiple lines, enclose in curly braces

C++: Conditional Execution

- For if/else:

```
if ( condition )
    statement 1
else
    statement 2
```

- Example:

```
int i1 = 0;
if (i1 < 2) {
  std::cout << "i1 is too small. Eat more." << std::endl;
}
else {
  std::cout << "i1 is big enough." << std::endl;
}
```

- Again: only SINGLE STATEMENTS come after, multiples must be in curly braces

C++: Conditional Execution

- Can nest or do sequences. CompPhys/ReviewCpp/BasicExamples/conditionals.cc

```
#include <iostream>

int main(void) {

  int i = 0;
  std::cout << "Enter a number: ";
  std::cin >> i;



  if ( i > 2 ) {
    std::cout << "This is greater than 2. Way too much!" << std::endl;
  } else{
    if( i == 2 ) {
      std::cout << "Phew! This is 2." << std::endl;
    } else if (i == 1) {
      std::cout << "So close, but this is only 1!" << std::endl;
    } else {
      std::cout << "Yuck, this is even less than 1." << std::endl;
    }
  }

  return 0;
}
```

C++: Conditional Execution

- But bools are just one single bit
- What if your expression gives you another type?
- Example:

```
#include <iostream>

int main(void) {

  int i = 0;
  std::cout << "Enter a number: ";
  std::cin >> i;

  if ( i + 5 ) {
    std::cout << "Tweet!" << std::endl;
  } else {
    std::cout << "Nuke!" << std::endl;
  }

  return 0;
}
```

Uhhh… what?

C++: Conditional Execution

- If your expression is cast to “0” (zero), then it is false
- If your expression is cast to “!0” (not zero), then it is true

- So this looks like one thing, and gives you something else you didn’t expect, but it is exactly what you told it to do:

```
#include <iostream>

int main(void) {

  int i = 0;
  std::cout << "Enter a number: ";
  std::cin >> i;

  if ( i = 5 ) {
    std::cout << "Nuke!" << std::endl;
  } else {
    std::cout << "Tweet!" << std::endl;
  }

  return 0;
}
```

As long as this is not equal to 5, we’re saved???

C++: Conditional Execution

- Logic operations are very useful here also:

- Like bitwise, but TWO symbols together
  - Logical and: &&
  - Logical or : ||
  - Logical not: !
  - Logical xor: ^^

Floating point and type concerns

C++: Narrowing

- Go to CompPhys/ReviewCpp/BasicExamples/narrowing.cc
  :

```
int main(void) {
  double d = 22000000000000.0;
  int i = d;
  std::cout << "d = " << d << ", i = " << i << std::endl;
  return 0;
}
```

- Now compile with the “-Wconversion” flag (enables conversion… don’t ask me why -Wall didn’t work last time):

```
> g++ -Wconversion narrow.cpp -o narrow
```

- and you get:

```
narrow.cpp: In function ‘int main()’:
narrow.cpp:9: warning: conversion to ‘int’ from ‘double’ may
alter its value
```

- And sure enough, if you try to run:

```
d = 2.2e+13, i = -2147483648
```

C++: Floating point comparison

- We've seen the "==" operator for ints
  - If we try "5 == 5", it returns "true"
  - If we try "1 == 0", it returns "false"
    - (unless you're KellyAnne Conway, in which case it returns "alternative_true")
  - If we try "5.0 == 5.0", what does this do?
    - What does this even mean?

C++: Floating point comparison

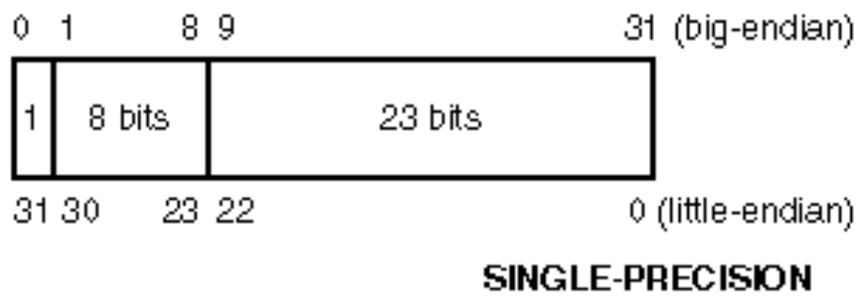
- CompPhys/ReviewCpp/BasicExamples/floatcompare.cc

```
#include <iostream>

int main(void) {

  float f1 = 5.0f;
  float f2 = 5.000000001f;

  if ( f1 == f2 ) {
    std::cout << "Nuke!" << std::endl;
  } else {
    std::cout << "Tweet!" << std::endl;
  }

  return 0;
}
```

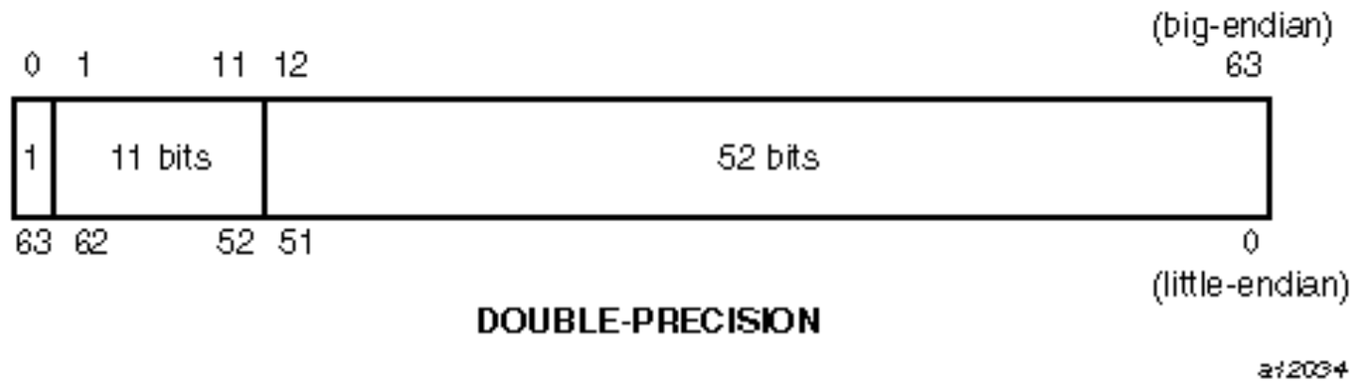
- Compile and run, what do you get?

C++: Floating point comparison

- Comparing floats only makes sense within the precision of the “mantissa”!



- Even still, terrible idea to try the “==“ operator



a=2034

- Better: assign a tolerance you can live with, and look if it is within the tolerance!
  - BAD: “f1 == f2”
  - GOOD: “std::abs(f1 - f2) < tolerance”
- You need to pick a tolerance your program needs
  - For C++ “tolerance”, you can use std::numeric_limits<double>::epsilon()

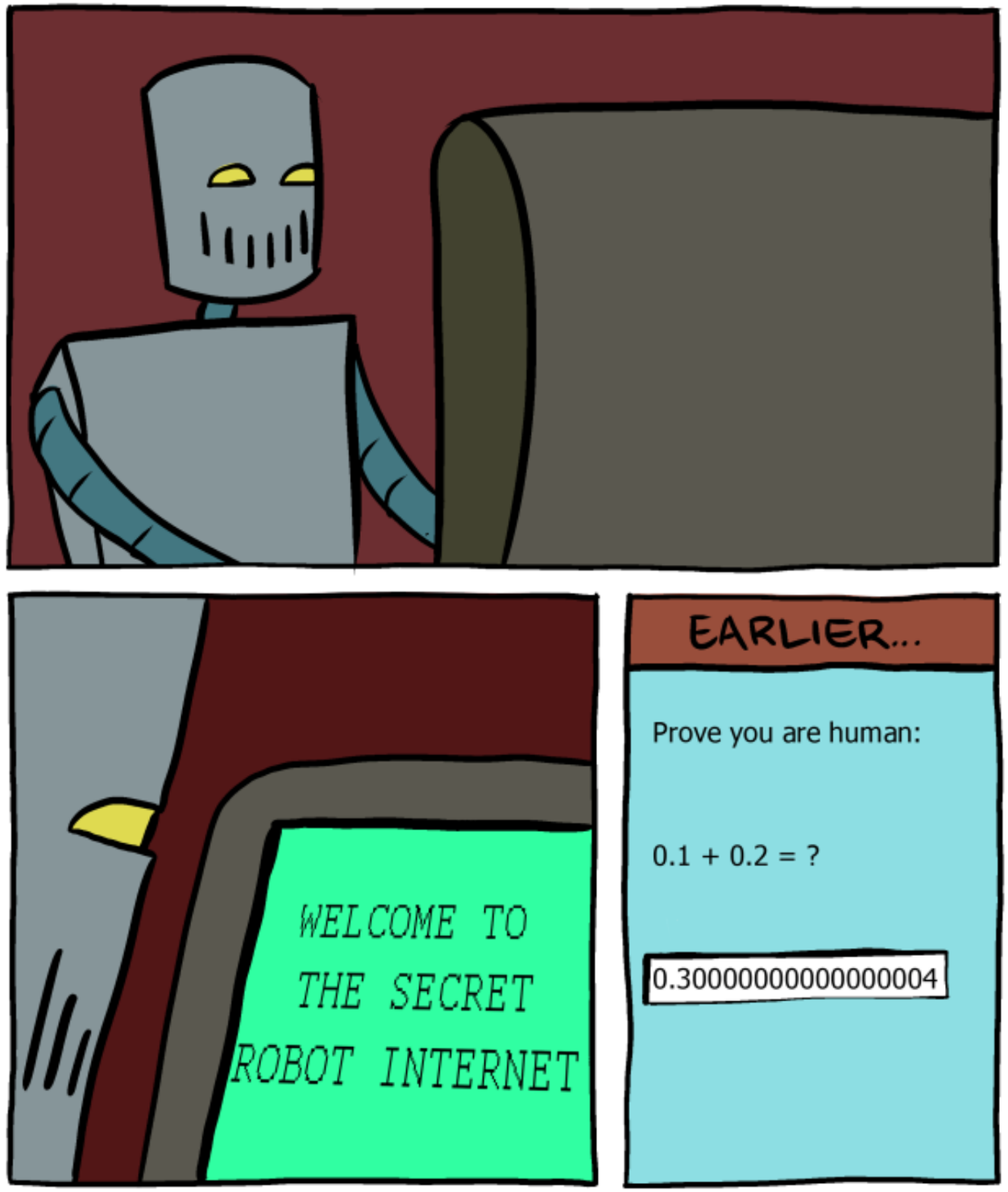
C++: Floating point comparison

- CompPhys/ReviewCpp/BasicExamples/floatcompare_better.cc

```cpp
include <iostream>
#include <cmath>
#include <limits>

int main(void){
  float f1 = 5.0f;
  float f2 = 5.000000001f;
  float tolerance = 0.01f;

  if ( std::abs(f1 - f2) < tolerance) {
    std::cout << "Nuke!" << std::endl;
  } else {
    std::cout << "Tweet!" << std::endl;
  }


  if ( std::abs(f1 - f2) < std::numeric_limits<float>::epsilon() ) {
    std::cout << "Within machine precision!" << std::endl;
  }
}
```

- Compile and run, what do you get?

C++: Floating point comparison



http://www.smbc-comics.com/?id=2999

Strings

C++: Strings

- You may have noticed that there is nothing for a BUNCH OF CHARACTERS together in C++
- This is called a “string” in other languages

- C++ has no intrinsic concept of a “string”, it’s just a bunch of “characters” lined up

- We will go over strings in detail later, but there is a library called the “Standard Template Library” that we’ve already seen (**#include <iostream>**)

- Now we will use the “strings” from the standard template library (**std**)
- Strings can basically use the standard logical expressions as you expect, but we will go into more later

C++: Strings

- CompPhys/ReviewCpp/BasicExamples/strings.cc

```cpp
#include <iostream>
#include <string>

int main(void) {

  std::string s1;
  std::cout << "Enter a string: ";
  std::cin >> s1;

  std::cout << "Your string is: " << s1 << std::endl;

  if (s1 == "Yay!") {
    std::cout << "Yay? Just what I was thinking!" << std::endl;
  }
}
```

- Grad students: you can utilize something like this for your HW's

Miscellania

C++: Switch

- There is another option for multiple-way “if” statements: “Switch”
- Just like a giant “if/else” statement, but easier to use
- Constraint: can only use on integer types

```
switch ( integral expression ) {
    case integral constant 1 :
        statement sequence 1
        break;
    case integral constant 2 :
        statement sequence 2
        break;
    case integral constant 3 :
        statement sequence 3
        break;
        .
        .
        .
    case integral constant n :
        statement sequence n
        break;

    default:
        default statement sequence
}
```